Many-Building Wind-Tunnel Experiments

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Objectives: In order to predict the dispersion of harmful materials released in or near an urban environment, it is important to first understand the complex flow patterns which result from the interaction of the wind with buildings and, more commonly, clusters of buildings. Recent advances in the application of computational fluid dynamics (CFD) models to such problems have shown great promise, but there is a need for high-quality data with which to evaluate CFD models. Although there is some experimental data for evaluation of CFD models (e.g., DOE Survey, 1997), this data is primarily limited to flow measurements around single buildings and/or to dispersion measurements around clusters of buildings. We have collaborated with the USEPA to perform high fidelity flow measurements around groups of buildings in their meteorological wind tunnel (Thompson and Snyder, 1985). This unique dataset of the mean and turbulent flow fields will be used to validate the physics and numerics of the DOE CFD codes and will be a valuable resource to the CFD community at-large.

Figure 1. Photo of the 2-d array of building blocks in the USEPA wind tunnel. The air flows left to right and fins and small blocks upstream create a

Recent Progress: High-resolution measurements of the three components of the mean and turbulent velocity statistics were obtained around a 2-D array of model buildings in the USEPA meteorological wind tunnel (see Fig. 1). Seven rectangular blocks (0.15 x 0.15 x 3.8m) were placed in the wind tunnel with their long face perpendicular to the flow and with a spacing of one building height (Hb) between the buildings. A pulsed-wire anemometer was used to measure mean velocity, turbulence intensity and some higher-order velocity statistics within and around the array. Multiple vertical profiles were taken from 3.3Hb upstream of the building array to 7.5Hb downstream of the array. Five vertical profiles were measured above each building rooftop and in the street canyon between the buildings in order to fully characterize the flow structure within the array. Surface pressure coefficient was measured on the upstream, rooftop and downstream faces of each building.

A number of interesting results have already been obtained. For example, rooftop

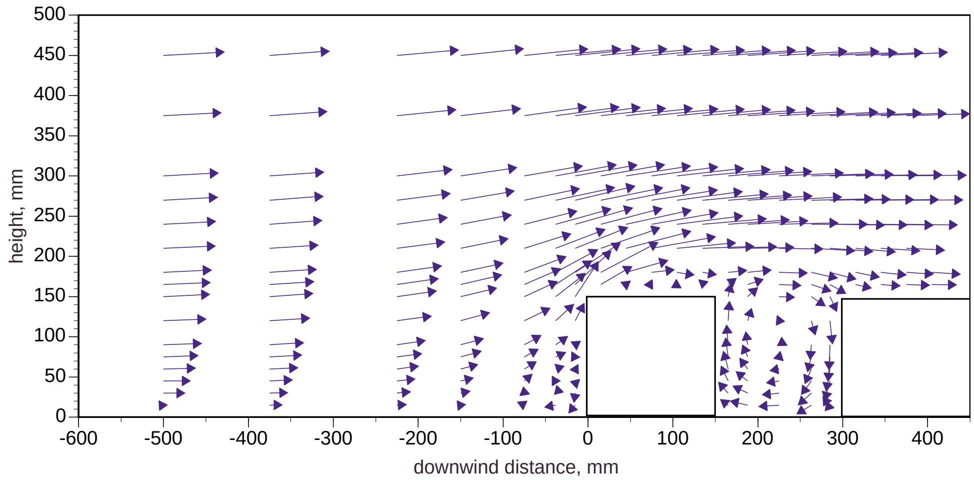

Figure 2. Wind-tunnel measurements of velocity vectors around and upstream of the first two buildings.

measurements show that the flow separates over the top of the first building, but not over the remaining downstream buildings, i.e., there is a recirculation region on the first rooftop, but not on the other rooftops (see Fig. 2). The flow at the surface, however, was nearly identical in all street canyons, where there was a strong recirculating region with reverse flow extending upward to about 0.6 building heights (see Fig. 3). The profiles downstream of the building array showed a separation cavity extending to approximately 3.5 building heights, followed by a gradual readjustment toward the approach-flow velocity profile.

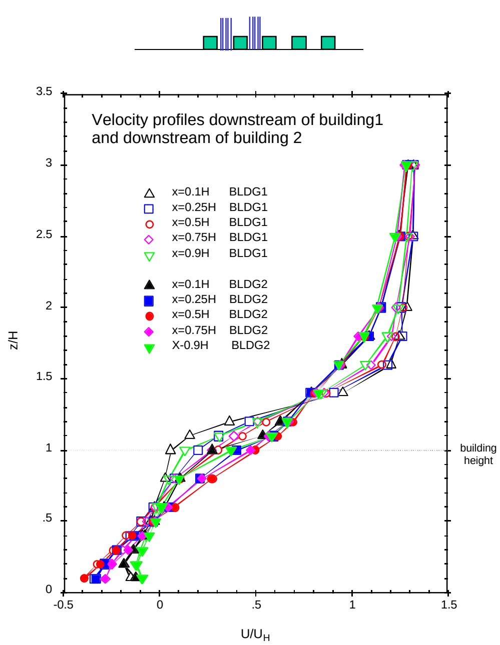

Figure 3. Measurements of the mean wind in the first two street canyons show similar reverse flow in the bottom half of the canyon. The winds are different in the upper half of the two canyons, providing a good test for CFD codes.

Future Outlook: The second phase of the experimental program will be conducted this summer. This will include mean and turbulent flow measurements around a 7x7 array of block buildings. This dataset will stress the three-dimensionality of the problem. CFD codes will be evaluated for their representation of the channeling and street corner vortex development. The summer experiments will also include some tracer releases and measurements of the concentration field within the 3-d array of buildings.

In the following years, we hope to conduct permutations of the experiments with the 3-d array of buildings. For example, changing the wind direction angle relative to the building faces or including one or two tall buildings will dramatically change the flow and dispersion patterns. These types of experiments would be good tests for the universality of the CFD physics and numerics. In addition, the results obtained can be used to help develop new "rules of thumb" for plume dispersion in building clusters. Finally, the building cluster flow measurements can be area-averaged and used to test the validity of the urban canopy parameterizations being developed for the mesoscale models.

References

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